The Core of the Great Attractor

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Abstract. The nature and extent of the Great Attractor (GA) has been the subject of much debate in the past decade, partly due to the fact that a large fraction of the GA overdensity is hidden by the southern Milky Way. Based on our deep optical galaxy search behind the southern Milky Way and a subsequent redshift survey we discovered that the Norma cluster (ACO 3627) in the GA region is a very massive cluster of galaxies. The cluster is comparable in size, richness and mass to the Coma cluster. It is located at the intersection of two distinct large structures, the Centaurus Wall and the Norma Supercluster. The velocity flow fields in the GA region are most likely caused by the confluence of these two massive structures where the Norma cluster constitutes its previously unseen but predicted core. The possibility that another, heavily obscured and yet uncharted rich cluster might form part of the GA overdensity is also discussed.

1. The Zone of Avoidance; the Milky Way as a natural barrier

Optical galaxy catalogues become severely incomplete towards the Galactic Equator due to the absorbing dust in the plane of the Milky Way which increasingly reduces the magnitudes and isophotal diameters of external galaxies. In the optical, as much as 20% of the extragalactic sky is obscured by the Galaxy.

This incompleteness severely constrains the studies of large-scale structures in the nearby Universe, the gravitational acceleration on the Local Group and other streaming motions, in particular in the region of the Great Attractor (GA). This nearby mass overdensity at $(\ell, b, v) \sim (320^\circ, 0^\circ, 4500$ km/s) (Kolatt et al. 1995) – centered in the Galactic Plane! – is largely hidden by the southern Milky Way.

The ambiguity about the nature and extent of the GA arises from the less than perfect match between the reconstructed mass density field and the galaxy density field (Dekel 1994). In other words, the peak in the mass density field is not always reflected by the galaxy distribution in redshift space. This raises the question whether light traces mass, or whether something else induces the observed streaming motions. The very existence of the GA has even been questioned (Rowan-Robinson 1993). Observational evidence for a Great Attractor, however, has grown (eg. the SBF Survey, Tonry et al., this volume).

Observing the galaxy distribution in the ZOA through multi-wavelength studies – optical, near-infrared, HI, X-ray – will in due time provide a clear answer on the various components of the GA. Is there still a considerable mass concentration hidden by the Milky Way (as suggested by the POTENT analyses)? Or is the GA associated with the Centaurus–Hydra–Pavo supercluster solely, without an additional massive component in the ZOA (Rowan-Robinson et al. 1990)?

2. Lifting the obscuring veil of the southern Milky Way

To address these questions, we have performed a deep optical search for partially obscured but still visible galaxies behind the Milky Way (Kraan-Korteweg 1989, Kraan-Korteweg and Woudt 1994a, Woudt 1998). Inspecting the IIIaJ film copies of the SRC Sky Survey, we identified over 8000 galaxies with $D \geq 0.2$ arcminutes in the general direction of the GA overdensity ($285^\circ \leq \ell \leq 340^\circ$ and $-10^\circ \leq b \leq 10^\circ$, Woudt 1998), the majority of which were previously unknown (97%).

This galaxy search significantly reduces the Zone of Avoidance: analyzing our diameter completeness limit as a function of the Galactic foreground extinction – as indicated by the DIRBE/IRAS reddening maps (Schlegel et al. 1998) – we could show that our galaxy catalogues are complete for galaxies with *extinction-corrected* diameters $D^o \geq 1\farcm3$ down to extinction levels in the blue of $A_B \leq 3\fm0$, respectively Galactic latitudes $|\,b\,| \gtrsim 3^\circ - 4^\circ$ of the area surveyed here.

The main outcome of this galaxy search in the GA region is the recognition that the Norma cluster (ACO 3627, Abell et al. 1989) in the Zone of Avoidance (a) is a rich and very massive cluster of galaxies, (b) is located at the core of the Great Attractor (Kraan-Korteweg et al. 1996, Woudt 1998), and (c) is comparable in mass and size to the well-known Coma cluster but even nearer in redshift space $(\ell, b, v) = (325.3^\circ, -7.2^\circ, 4844$ km/s).

3. The Norma cluster (ACO 3627)

In this section, we describe the main properties of this cluster. Within the Abell radius of the Norma cluster (3 h_{50}^{-1} Mpc), 603 galaxies with a major diameter $D \geq 0\farcm2$ were discovered in our galaxy search. Within the core radius, a large fraction (48%) are early type galaxies (Woudt 1998).

With our follow-up redshift survey, redshifts were obtained for 266 (44.1%) of the galaxies in the Abell radius (only 17 redshifts were known before our survey). 219 are likely cluster members. The velocity distribution of these

galaxies is close to Gaussian. A more detailed statistical analysis (following Pinkney et al. 1996) reveals, however, significant substructure within the Abell radius: the Norma cluster consists of a main cluster at a redshift of 4844 $\pm$ 63 km/s with a velocity dispersion of 848 km/s, and of a spiral-rich subcluster falling into the main cluster (Woudt 1998).

With these new observations, we can now clearly identify two distinct structures that cross the Galactic Plane in the Great Attractor region:

• The Centaurus Wall (Fairall 1998), tilted about 15 degrees to the Supergalactic Plane. It extends in redshift-space from 0 - 6000 km/s and includes the Virgo Supercluster, the Centaurus cluster and the Norma cluster.

• A massive broad structure between $4000 \leq v \leq 8000$ km/s. This broad structure, dubbed the Norma Supercluster, runs at a slight angle with respect to the Galactic Plane. It can be traced from the Pavo cluster (Fairall et al. 1998) to the Norma cluster (its centre) where – at slightly higher redshifts – it bends towards the Vela Supercluster (Kraan-Korteweg and Woudt 1994b) .

The observed peculiar velocity field in the Great Attractor most likely results from the confluence of these two massive structures. The Norma cluster is located at the intersection of these two structures. With a mass of 0.9×10^{15} $M_{\odot}$ (within a 3 h_{50}^{-1} Mpc radius) it is the most massive cluster of galaxies in the Great Attractor overdensity – and on par with the well-known Coma cluster. Simulations show that the Coma cluster would appear practically identical to ACO 3627 if it were located at the same position, ie. at the same redshift distance and subjected to the same mean foreground extinction ($A_B = 1\overset{m}{.}1$, Woudt 1998).

An R_C and I_C Tully-Fisher analysis of the Norma cluster yields a relative distance modulus to the Virgo cluster of $(m-M)_{\rm Norma} - (m-M)_{\rm Virgo} = 2\overset{m}{.}9 \pm 0\overset{m}{.}2$ and a peculiar motion of the cluster with respect to the rest frame of the Cosmic Microwave Background radiation of 461 $\pm$ 410 km/s (Woudt 1998). Our data do not confirm the previously reported peculiar motion of ACO 3627 of 1760 $\pm$ 355 km/s (Mould et al. 1991). Within the uncertainty of the assumed extinction correction our data are consistent with the Norma cluster being at rest with respect to the Cosmic Microwave Background radiation. It therefore is *the* most likely candidate for the Great Attractor's previously unseen core.

4. Clustering in the GA region

One cannot exclude the possibility that other rich clusters (like the Norma cluster) reside in the GA region, hidden behind the deepest extinction layers of the Milky Way. A rich cluster such as the Norma cluster (at the distance of the Great Attractor) would be fully obscured if the extinction at optical wavelengths is larger than $A_B \gtrsim 10$ mag. This corresponds to the inner $\pm$2–3 degrees of the plane of the Milky Way. If such a cluster does exist, it could be detected by its X-ray emission, but also by the radio continuum emission of a central radio source, such as PKS1610-608 in the Norma cluster.

A suspect for such a cluster candidate is actually given with the strong extragalactic radio source PKS1343-601 (McAdam 1991): hidden behind 12 magnitudes of extinction (A_B), this radio source at $(\ell, b, v) = (309.7^\circ, 1.7^\circ, 3872$ km/s$)$ could mark the bottom of the potential well of another cluster in the GA over-

density (Woudt 1998). There are clear indications from the redshift-distribution of HI-detected galaxies (Kraan-Korteweg and Juraszek 1999) that this is indeed the case. We furthermore have obtained deep I-band images of this region with the MPG-ESO 2.2-m telescope and the Wide Field Imager. A first inspection of the central field of this suspected cluster revealed a large number of galaxies – despite the severe extinction of $A_I = 4\overset{m}{.}5$ in the I-band at the position of PKS1343-601.

5. Conclusions

A clearer picture of the optical galaxy distribution in the general GA region has emerged with the recent studies of the galaxy distribution behind the southern Milky Way; two distinct extended structures at the redshift distance of the GA cross the Galactic Plane, ie. the Centaurus Wall and the Norma supercluster. The Norma cluster – found to be a massive and rich cluster behind the southern Milky Way – is located at the intersection of these two massive structures and marks the core of the GA overdensity.

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References

Abell, G.O., Corwin, H.G. and Olowin, R.P. 1989, ApJS 70, 1

Dekel, A. 1994, ARA&A 32, 371

Fairall, A.P., Woudt, P.A. and Kraan-Korteweg, R.C. 1998, A&AS 127, 463

Fairall, A.P. 1998, *"Large-Scale Structures in the Universe"*, eds. John Wiley and sons, Praxis Publishing, Chichester UK

Kolatt, T., Dekel, A. and Lahav, O. 1995, MNRAS 275, 797

Kraan-Korteweg, R.C. 1989, in Reviews in Modern Astronomy 2, ed. G. Klare, Springer: Berlin, 119

Kraan-Korteweg, R.C. and Woudt, P.A. 1994a, A.S.P. Conf.Ser. 67, 89

Kraan-Korteweg, R.C. and Woudt, P.A. 1994b, in Cosmic Velocity Fields, eds. F. Bouchet and M. Lachièze-Rey, Editions Frontières, 557

Kraan-Korteweg, R.C., Woudt, P.A., Cayatte, V., et al. 1996, Nature 379, 519

Kraan-Korteweg, R.C. and Juraszek, S. 1999, PASA, submitted

McAdam, W.B. 1991, PASA 9, 225

Mould, J.R., Staveley-Smith, L., Schommer, R.A., et al. 1991, ApJ 383, 467

Pinkney, J., Roettiger, K., Burns, J.O., et al. 1996, ApJS 104, 1

Rowan-Robinson, M., Lawrence, A., Saunders, W., et al. 1990, MNRAS 247, 1

Rowan-Robinson, M. 1993, Proc.Natl.Acad.Sci. 90, 4822

Schlegel, D.J., Finkbeiner, D.P., Davis, M. 1998, ApJ 500, 525

Tonry, J., Ajhar, E., Blakeslee, J., et al., this volume

Woudt, P.A. 1998, Ph.D. thesis, University of Cape Town.